the collocated four fiber optic conduits. The low probability of liquefaction (20%) and the delay due to congestion (7 days) results in a 1 day increase in the probable restoration time. The pipelines enter a third liquefaction zone near Blue Cut. There the petroleum products pipelines cause delays in the repair of the fiber optic cables. The fiber optic cables do not impact the pipelines, and there is no collocation impact on the pipelines.

At the San Andreas Fault the pipelines are collocated with high voltage power lines and a 36-inch natural gas pipeline. Because the petroleum pipelines are located for several miles along the fault rift zone, there will be a lengthy delay of several months while the suitability of allowing them to relay the pipeline along that route is resolved with the regulatory authorities. However, that is not a collocation issue unless the pipelines are to be rerouted near the existing natural gas pipeline. However the damage scenario includes an explosion/fire, which will increase the amount of pipeline that must be exposed and inspected. In addition, the general congestion and environmental mitigation activities will cause a 30 day delay, for a probable increase in the pipeline restoration time due to collocation of 30 days. Thus, the total increase in the probable time to restore service for these pipelines is about 41 days, most of that impact is due to conditions at the fault rift zone.

Ninety-three collocations involving fuel pipelines were analyzed during this study. A summary of the collocation impacts is:

Lifeline	Increase in Probable Time to Restore Service, days	Increase in Probable Time to Restore Service, %
Western Natural Gas 36-inch Pipeline	57	86
Eastern Natural Gas 36-inch Pipeline	25	83
Natural Gas 16-inch Pipeline	8	80
Petroleum Products Pipelines	41	63

Transportation Lifelines

The Cajon Pass has been used for critical transportation routes since early times. At present it is used by the Southern Pacific, Santa Fe, and Union Pacific railroads, and Interstate Highway I-15. In addition, there are connecting highways, including the I-215 spur into San Bernardino, State Route 138 coming from the west into the Pass from Palmdale and continuing to the lake district in the east, and a partially abandoned section of old Federal highway U.S. 66, now called the Cajon Blvd. extension. The routes of these lifelines in Cajon Pass is shown in Figure 24. The location of the photographs presented in this section of the report are also shown on the figure.

Because these routes are discontinuous in the sense that each bridge, each change in MMI intensity, and each local liquefaction or landslide area must be separately checked. The railroads had to be segmented into 30 separate analysis sections and the I-15 highway into 36 separate analysis sections. During the vulnerability analysis of these facilities, it was necessary to consider some extension outside the study area in order to provide realistic estimates of time to restore service. In the case of the Southern Pacific Railroad, for example, the route considered was extended to the Highland Boulevard over-crossing in San Bernardino. The assumptions with regard to equipment available to make repairs differs from that used for the pipeline and communication lifelines in that it is assumed that the railroads and highways both have local active maintenance yards with their own heavy equipment for construction activities. While some of this may be pressed into service for life saving activities in the early emergency phase, it is not likely that this will prevent immediate inspection and reconnaissance. Therefore, no delay time waiting for equipment availability was assumed.

Moving this equipment to the most critical sites along the transportation lifeline, on the other hand, may present a significant problem of access because the equipment must move along the lifeline facility itself. In each analysis, it is first assumed that the equipment must work from one end or the other of the Cajon Pass, repairing each section as it goes before it can reach the next section. The probable access time to a given section is the sum of the products of times to repair all sections up to that point multiplied by their respective probability of damage. For the conditions existing in the Cajon Pass, this leads to very long access times for those sections remote from the Pass entrances. A second analysis was therefore made in which the possibility of construction of temporary by-passes around damaged sections to permit the access of construction equipment to more critical sites was considered (this, of course, only applies to the highway portions of the transportation lifelines). The access time to a given site in that situation became the sum of the products of the by-pass times and the probability that each of them is required because of the damage in the section being analyzed. Some of the highway bridges on I-15 have built in by-pass capability, since they are part of "diamond" interchanges in which the ramps may serve this purpose. In the generally dry conditions of Cajon Pass, it is possible in many cases to simply drive across country in tracked vehicles and lightly loaded four wheel drive trucks. Some road bed material would need to be placed to support heavy highway construction equipment.

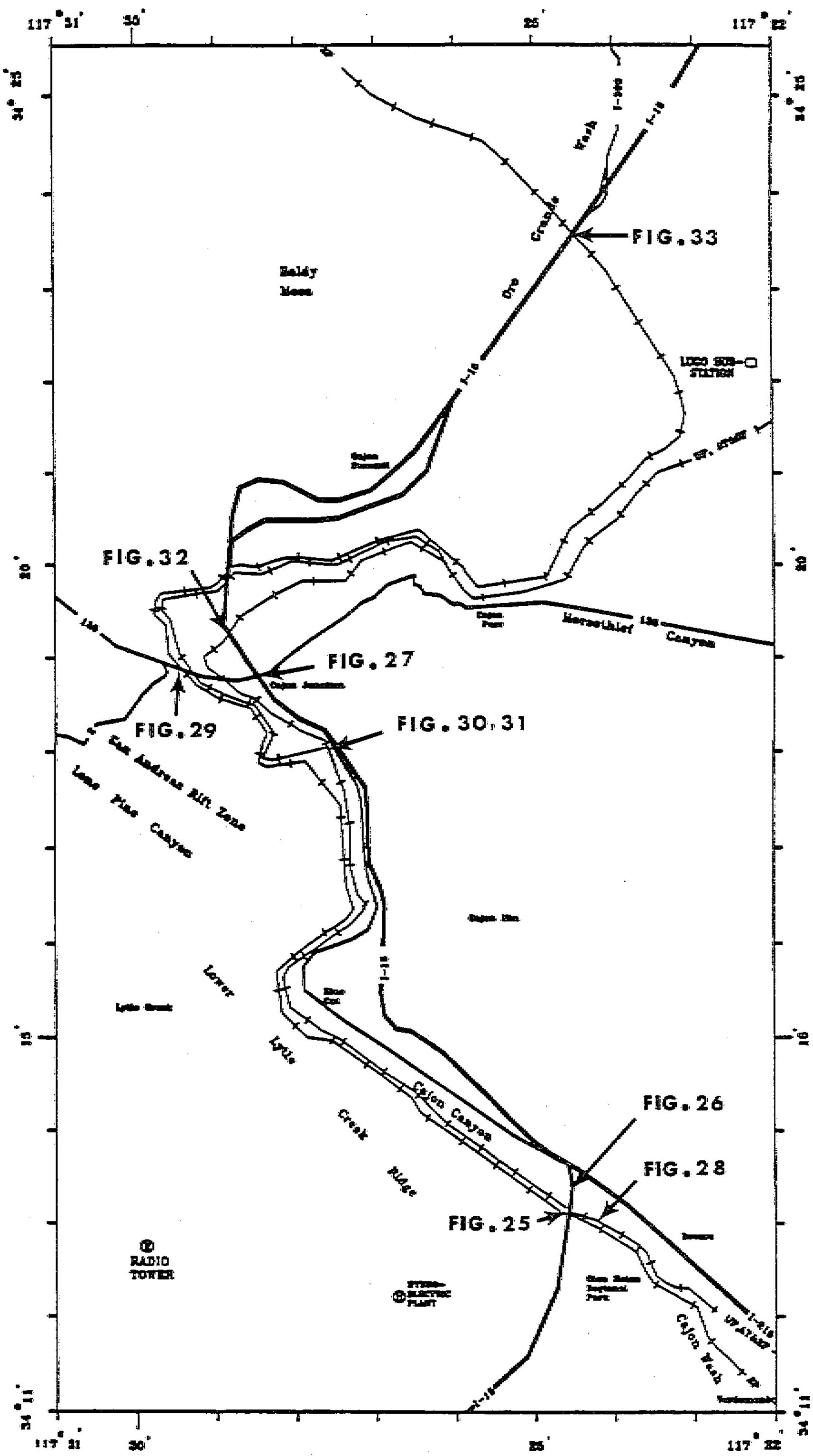

Figure 24, TRANSPORTATION LIFELINE ROUTES

SCALE

0 1 2 MILES

0 1 2 KILOMETERS

N

EXPLANATION

I-15 INTERSTATE

2 PAVED HIGHWAY

RAILROAD

Larger Scale Figure Located at End of Document

The purpose of these extended access time analyses was to find the critical total time for the lifeline section being evaluated, that is, the time to gain access to the site with repair equipment plus the time to carry out the needed repairs. As in the case of pipelines and power lines, each lifeline was first divided into sections, such that the conditions within each section were reasonably homogeneous. Because of the presence of many bridges on the highways and railroads, this leads to more sections for the roughly 25 miles of length of each separate transportation system. Prior to the detailed analysis of the lifeline section being

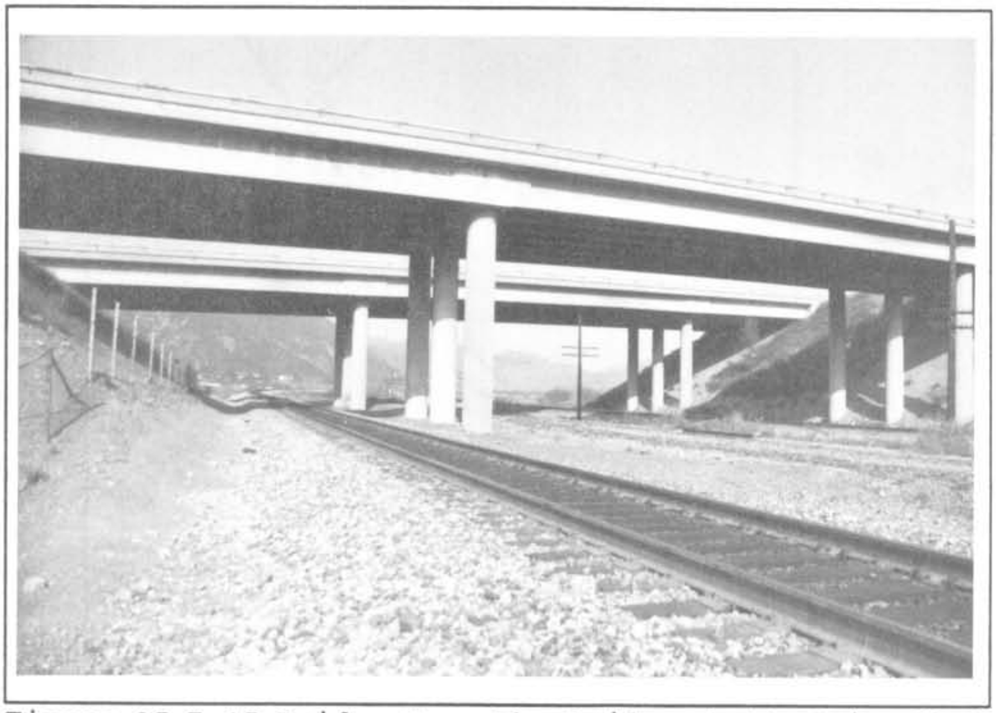

Figure 25 I-15 Bridge Over The Railroads In Cajon Wash

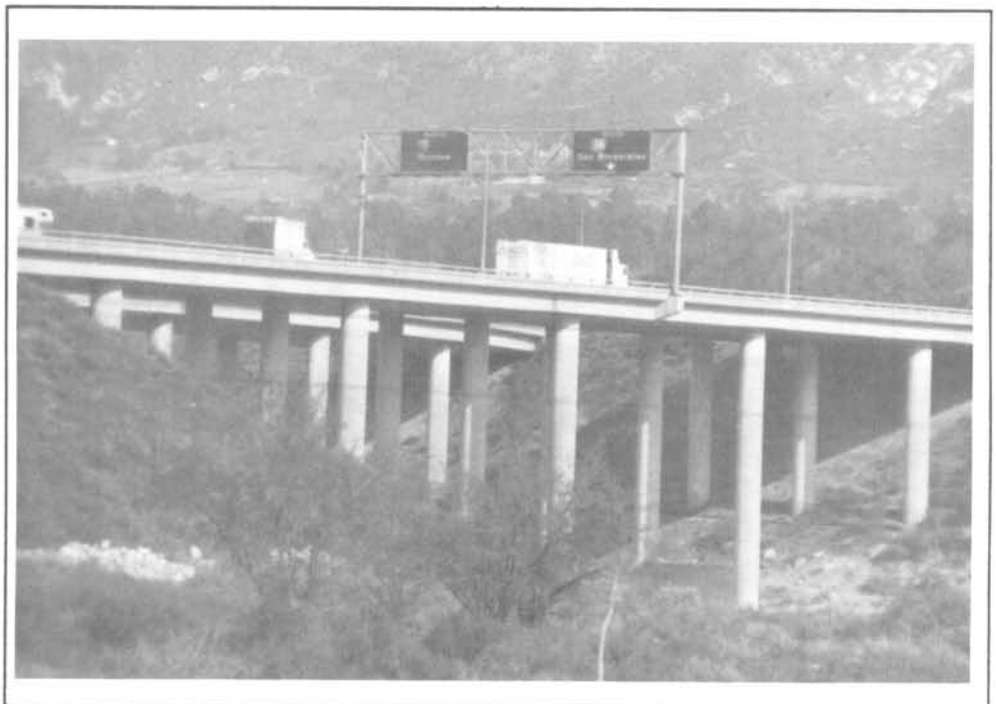

Figure 26 I-15 Bridge Over Cajon Wash

considered, the Bridge Vulnerability Index of each of these structures had to be determined, and the probable extent and type of damage to each postulated.

The highway bridges along Interstate I-15 were, for the most part, built in the late 1960's, except for the section over Lytle Creek Wash. Although they are in an area generally considered to be "California region 7", the status of retrofit is somewhat irregular. In this analysis, they are considered to be "California region 3-6" until proved to qualify for the higher degree of safety. Nevertheless, none of these bridges are expected to completely collapse, although partial collapse of several is possible. The I-15 bridge over the railway lines (Figure 25) and the high level I-15 bridge over Cajon Wash (Figure 26) are vulnerable, and there is some possibility of the partial collapse of the steel girders over I-15 at its junction with highway 138 (Figure 27).

Many of the railroad bridges in the Cajon Pass are over 50 years old, but most are in relatively good condition. As noted in the discussion of the development of the Bridge Vulnerability Index, many of these bridges have inherent resistance to lateral loads. There are, however, several multiple simple span bridges over poor soil conditions (including possible liquefaction), such as both the Southern Pacific and Santa Fe bridges over the lower end of Cajon Wash (Figure 28). There are several more such crossings over the Cajon Creek and its branches. There is also a large two span, through plate, girder bridge on the Southern Pacific railroad over Highway 138 which is sharply skewed, and which has bearings which are vulnerable to loss (Figure 29). It is expected that the multiple span structures will have one or more spans dislodged where they are subjected

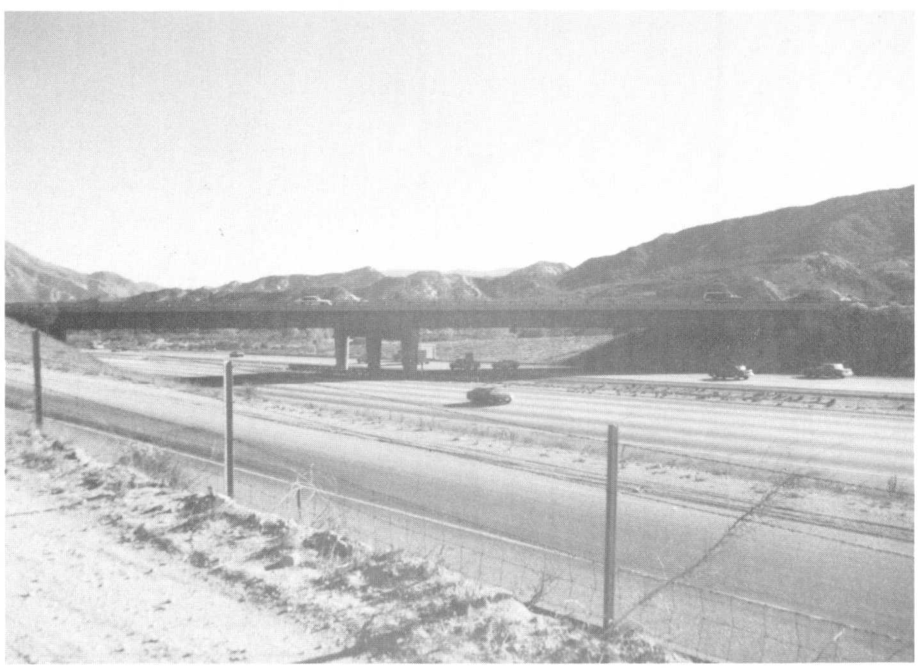

Figure 27 Highway 138 Bridge Over I-15